NEW YORK CITY COLLEGE OF TECHNOLOGY
THE CITY UNIVERSITY OF NEW YORK

Department of Radiologic Technology & Medical Imaging

RAD 2326

Radiographic Physics
Course Outline & Learning Outcomes

Fall 2024
Professor DeVito
Room A-407
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Office hours: TBA

Note: All other course related documents can be found on Blackboard.

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New York City College of Technology/CUNY
Department of Radiologic Technology & Medical Imaging

Fall 2024

COURSE: RAD 2326 - **Radiographic Physics**
2cl. hrs, 2 cr (fall only)

INSTRUCTOR: Professor Anthony F. DeVito **OFFICE:** Room A 407

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OFFICE HOURS: TBA

COURSE DESCRIPTION

Instruction in the principles of x-ray generation and properties of x-ray circuits and equipment. Basic principles of quality management are covered.

PREREQUISITES: RAD 1225, RAD 1226, RAD 1227, RAD1228, RAD 1229

COREQUISITES: RAD 2325, RAD 2327, RAD 2328

COURSE OBJECTIVES:

Upon completion of RAD 2326, students will be able to:

1. Describe the principles of x-ray generation and properties of x-radiation.
2. Have knowledge of the components of and function of basic radiographic units.
3. Calculate problems using fractions, exponents and algebraic equations.
4. Discuss x-ray interactions and beam spectrum
5. Discuss x-ray generator, transformer, rectification system and circuits.
6. Describe the methods of establishing and maintaining a radiographic quality assurance program.
7. Provide an overview of quality assurance principles and practices.
8. Perform tests and evaluations associated with quality management.

REQUIRED TEXTBOOK:

1. Bushong, Stewart C., Radiologic Science for Technologists - 9th ed., Mosby Co., 2009

2. Carlton & Adler. Principles of Radiographic Imaging – An Art and a Science - 5th ed., Delmar., 2013.

COURSE REQUIREMENTS AND ASSESSMENT

Students enrolled in RAD 2326 must:

1. Attend and actively participate in all lecture sessions
2. Complete all in-class, online, and homework assignments
3. Obtain lecture materials and study questions posted on blackboard approximately one week before each class for the entire semester.
4. Meet on blackboard when indicated by the instructor.
5. Participate in all **scheduled** exam and quiz sessions.

Note:
All quizzes will be given during the last 20 minutes of class. Students who are absent will NOT be given a make-up quiz. A grade of zero will be entered for quizzes missed. The lowest quiz grade only will be dropped at the end of the semester.

COURSE GRADING

Class Participation:

Students are expected to participate in all classes and class activities through discussion, inquiry and individual or group activities both in the classroom and in the laboratory sessions.

Average of quizzes and homework	15%
Course Participation (includes day to day participation in class and class activities)	10%
Midterm Exam	25%
Project on Writing	10%
Final Exam	40%
	100%

ATTENDANCE POLICY

No more than ***2*** absences will be allowed in this course. Each additional absence (excused or unexcused) will lower your course grade by one letter grade. This means that if your average is A and you were absent three times, the highest grade you can achieve is A-. And if you were absent 4 times, the highest grade you can achieve is B+. In general, students in the Rad Tech major must maintain grades that are above C.

All quizzes will be given during the last 15 minutes of class. Students who are absent will NOT be given a make-up quiz. A grade of zero will be entered for quizzes missed. The lowest quiz grade will be dropped.

NOTE: Detailed college attendance policy may be found in the college catalog.

LATENESS

Arrival 10 minutes after the scheduled start of class time will be counted as lateness. Two late arrivals to class will be counted as one absence and may affect the final course grade.

CLASSROOM CONDUCT

- ✓ No cellular phone interruptions during class (**Turn off before class**).
- ✓ No talking during instructor's lectures or when another student is speaking.
- ✓ Food and drinks are not allowed in the classroom at any time

NEW YORK CITY COLLEGE OF TECHNOLOGY POLICY ON ACADEMIC INTEGRITY:

Students and all others who work with information, ideas, texts, images, music, inventions, and other intellectual property owe their audience and sources accuracy and honesty in using, crediting, and citing sources. As a community of intellectual and professional workers, the College recognizes its responsibility for providing instruction in information literacy and academic integrity, offering models of good practice, and responding vigilantly and appropriately to infractions of academic integrity. Accordingly, academic dishonesty is prohibited in The City University of New York and at New York City College of Technology and is punishable by penalties, including failing grades, suspension, and expulsion. The complete text of the College policy on Academic Integrity may be found in the catalog.

RAD 2326 Radiographic Physics
Reading Assignments, Quiz and Exam Schedule

"Please read the referred chapters/pages *before* coming to class"

DATE	WEEK	Bushong Assigned Reading	TOPIC	EXAM QUIZ
	1	Review Chap. 2	Measurement Systems & Mechanics	
	2	Chap 3 p 41-48, Chap 4 & 5	Atomic Structure & Electricity	
	3	Chap 5	Electricity Cont. & Magnetism	**Quiz 1**
	4	Chap 5	Electromagnetism & Transformers	
			NO CLASSES	
	5	Chap 7	The X-ray Tube & Tube Failure	**Quiz 2**
	6	Chap 6	Operating Console; Exposure Timers & Voltage Rectification	
	7		**Midterm Exam** Review materials from weeks 1- 6 only	**50 quests.**
	8	Chap 6	The X-ray Circuit	
	9	Chaps 8	Production of X-ray & Beam Characteristics	
	10	Review Chap. 16 Read Chap 18	Basic Concepts of Quality Management	**Quiz 3**
	11	Review Chap. 16 Read Chap 18	QA/QC, Visual and Manual Inspection	
	12	Chap 18	Evaluation of the Radiation Beam Output	
		COLLEGE IS CLOSED	**NO CLASSES SCHEDULED**	
	13	Chap 18	Evaluation of Beam Quality	**Quiz 4**
	14	Chaps 17, 18 & Chap 30	Evaluation of Beam Geometry, FSS, IS Parameters and Grids	
TBA	**15**		**Final Exam**	**100 quests.**

Week

I. MEASUREMENT SYSTEMS & MECHANICS

- **A. Units of Measurement**
  - 1. Systems
  - 2. SI Base Units
  - 3. SI Derived Units
- **B. Velocity**
  - 1. Definition
  - 2. Units
  - 3. Average Velocity
- **C. Acceleration**
  - 1. Definition
  - 2. Units
- **D. Inertia**
  - 1. Definition
- **E. Force**
  - 1. Definition
  - 2. Units
  - 3. Weight/Gravity
- **F. Momentum**
  - 1. Definition
- **G. Work**
  - 1. Definition
  - 2. Units
- **H. Power**
  - 1. Definition
  - 2. Units
- **I. Energy**
  - 1. Definition
  - 2. Units
  - 3. Conservation
  - 4. Mechanical
  - 5. Thermal
- **J. Math Review**

II. ATOMIC STRUCTURE & ELECTRICITY

- **A.** Matter and energy
  - 1. Basic structure of matter
  - 2. Concepts of atomic theory
  - 3. Atomic nomenclature
- **B.** Electromagnetic Energy
  - 1. Electromagnetic spectrum
- **C. Electrostatic Charge**
  - 1. Unitary Nature
  - 2. Electrification
- **D. Coulomb's Law**
  - 1. Repulsion/Attraction
  - 2. Electrostatic Force
- **E. Other Electrostatic Principles**
  - 1. Movement of Negative Charges
  - 2. Distribution of Charges
  - 3. Concentration of Charges

III. ELECTRICITY Cont. & MAGNETISM

- **A. Electrical Potential**
  - 1. Definition
  - 2. Units

- **B. Current**
  1. Definition
  2. Units **RAD 2326 Course Outline**
- **C. Resistance**
  1. Definition
  2. Units
- **D. Ohm's Law**
  1. Statement
  2. Examples
- **E. Simple Circuit**
  1. Elements
  2. Symbols
- **F. AC vs. DC**
  1. Definitions
  2. Frequency
  3. Applications
- **G. Measuring Devices**
  1. Galvanometer
  2. Ammeter
  3. Voltmeter
- **H. Protective Devices**
  1. Ground
  2. Fuse
  3. Circuit Breaker

IV. ELECTROMAGNETISM & TRANSFORMERS

- **A. Electromagnetic Induction**
  1. Mutual Induction
  2. Self Induction
- **B. Coils/Electromagnets**
  1. Principle
  2. Applications
- **C. Electrical Generators**
  1. Principle
  2. Components
  3. Types
- **D. Motors**
  1. Principle
  2. Components
  3. Types
- **E. Transformers**
  1. Structure
  2. Principle of operation
  3. Types
  4. Efficiency
  5. Transformer Law
- **F. Current/Voltage Control Devices**
  1. Types
  2. Operating Principles

V. THE X-RAY TUBE & TUBE FAILURE

- **A. Anode**
  1. Definition
  2. Types
  3. Structure
  4. Characteristics
- **B. Cathode**
  1. Definition
  2. Types

3. Structure
4. Characteristics

C. Envelope
1. Purpose
2. Description

D. Cables
1. Description

E. Thermal Characteristics
1. Instantaneous rating
2. Heat Capacity

F. Advanced Design Features
1. Anode features
2. Cooling methods

VI. OPERATING CONSOLE, EXPOSURE TIMERS & VOLTAGE RECTIFICATION

A. Operating console components
1. Line compensation
2. kV control
3. mA control

B. Principle
1. Mechanism
2. Types
3. Effective voltage/Ripple
4. Circuitry

C. Rectifiers
1. Types
2. Efficiency
3. Advantages & disadvantages of various types

D. Failure
1. Probability
2. Consequences

E. Manual
1. Types
2. Capability
3. Limitations

F. Automatic/Phototiming
1. Types
2. Capability
3. Limitations

VII. THE X-RAY CIRCUIT

A. Components and functions of the low-voltage portion
1. Main switch
2. Breakers
3. Line voltage control
4. Kilovoltage control
5. Timing
6. Meters and indicators
7. Primary of main transformer

B. Components and functions of the high-voltage portion
1. Secondary of main transformer
2. Meters
3. Rectification system
4. X-ray tube

C. Components and functions of filament circuit
1. Ma selector
2. FS selector

3. Filament transformer
4. Filament

D. Converter power/Medium frequency generators
1. Principle
2. Applications

E. Battery powered equipment
1. Principle
2. Applications

F. Capacitor discharge equipment
1. Principle
2. Applications

VIII. MIDTERM EXAMINATION

IX. PRODUCTION OF X-RAY & BEAM CHARACTERISTICS

A. Principle/Necessary Conditions
1. Electron cloud/space charge
2. Acceleration
3. Deceleration

B. Processes
1. Bremsstrahlung
2. Characteristic

C. Parameters
1. Energy
2. Intensity

D. Influences
1. mA
2. KV
3. Filtration
4. Voltage Waveform
5. Target Material

X. BASIC CONCEPTS OF QUALITY MANAGEMENT

A. Definitions
1. Quality Assurance
2. Quality Control

B. Rationale
1. Dose
2. Diagnosis
3. Dollars

C. Personnel responsibility
1. Radiologist
2. Radiologic Physicist
3. Chief Technologist
4. QC Technologist
5. Engineer
6. Other staff

D. Regulatory requirements
1. Joint Commission on the Accreditation of Hospitals
2. New York State Requirements
3. Federal guidelines

E. Establishing standards for radiographic quality
1. Satisfactory
2. Adequate
3. Dependable
4. Economic

F. Requirements for quality control procedures
1. Comprehensive procedure manual
2. Appropriate equipment
3. Adequate training of personnel
4. Careful recordkeeping
5. Regular test review and evaluation

G. Control charts
1. Definition
2. Examples
3. Determining the initial operating level
4. Establishing control limits
5. Measurement error: systematic and random

H. The room log
1. Room equipment survey/inventory
2. Quality control procedures
3. Control charts
4. Maintenance logs
5. Sample images

I. Reject/repeat analysis
1. Definitions
2. Rationale
3. Film collection and analysis categories
4. Reject rates: calculation and examples

XI. QA/QC, VISUAL AND MANUAL INSPECTION

A. Checking for sources of fogging
1. Visual inspection for white light leaks
2. Darkroom fog check (safelight test)
a. use of pre-exposed film
b. time intervals
c. acceptable levels

B. Establishing a processor QC program
1. Equipment required
a. sensitometer
b. densitometer
c. thermometer
d. stopwatch
3. box of film
2. Initial measurements
a. six sensitometric strips
b. average density of each step
c. average base-plus fog
d. selection of monitoring steps
e. sample processor control forms
f. recording the data

C. Daily monitoring
1. General check of processor
a. time of day
b. solution and dryer temperature
c. visual inspection
d. clean-up sheets
2. Sensitometry
a. sensitometric strips from control box
b. reading and recording the densities
c. recording other processor data

d. comparison with control limits
e. presence of trends
f. recording corrective actions

D. Equipment needed for visual/manual inspection
1. Tape measure
2. Carpenter's level

E. Procedure: visual/manual inspection of:
1. Tube, tube stand, locks, and cables
2. Field light and bucky center light
3. Tube angulation indicator, SID indicator
4. Table switches, bucky lock and cassette lock
5. Table angle indicator and center stop
6. Table foot board and shoulder rests
7. Step stool
8. Panel switches, lights and meters
9. Hand switch placement
10. Overload protection
11. Fluoroscopic tower locks, switches, and lights
12. Fluoroscopic tower motion and power assist
13. Compression device
14. Television monitor
15. Fluoroscopic grid, drapes, and bucky slot cover
16. Spot film travel
17. Gonad shields, aprons, and gloves
18. View box cleanliness and light uniformity
19. Storage and rotation of unexposed film

XII. EVALUATION OF THE RADIATION BEAM OUTPUT

A. Timer accuracy
1. Equipment required
2. Procedure
3. Interpretation and acceptance limits

B. Reproducibility of exposure
1. Equipment required
2. Procedure: manual timing
3. Procedure: phototiming
4. Interpretation and acceptance limits
5. Calculation of mR/mAS

C. Generator linearity
1. Equipment required
2. Procedure
3. Interpretation and acceptance limits

XIII. EVALUATION OF BEAM QUALITY

A. Accuracy of KVP calibration
1. Description of KV test cassette
2. Procedure
3. Interpretation and acceptance limits
4. Other devices

B. HVL measurement
1. Equipment needed
2. Procedure
3. Interpretation and acceptance limits

C. Adequacy of filtration
1. Equipment needed
2. Procedure
3. Interpretation and acceptance limits

XIV. EVALUATION OF BEAM GEOMETRY, FOCAL SPOT SIZE, INTENSIFYING SCREEN PARAMETERS AND GRIDS

A. Light field congruence with the x-ray field
1. Equipment needed
   a. nine-penny test
   b. field test template
2. Procedure
3. Interpretation and acceptance limits

B. Perpendicularity of the CR
1. Equipment needed
2. Procedure
3. Interpretation and acceptance limits

C. Beam restriction accuracy
1. Equipment needed
2. Procedure: manual collimation
3. Procedure: PBL devices
4. Interpretation and acceptance limits

D. Accuracy of tube-bucky centering (grid alignment)
1. Equipment needed
2. Procedure
3. Interpretation and acceptance limits

E. Homogeneity of exposure when using a grid
1. Equipment needed
2. Procedure
3. Interpretation: CR angulation vs. de-centering

F. Intensifying screen condition
1. Inspection
2. Cleaning

G. Film-screen contact
1. Equipment needed
2. Procedure
3. Interpretation

H. Uniformity of screen speed
1. Equipment needed
2. Procedure
3. Interpretation and acceptance limits

XV. Final Exam

RAD 2326 Learning Outcomes

Week 1

Condition: Lecture, discussion and assigned reading on measurement systems and on concepts of mechanics.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. List the SI units of mass, length, and time.
2. List the SI units for velocity, acceleration, force/weight, work/energy and power.
3. State verbal definition and define formula for velocity and average velocity.
4. Define Newton's laws of inertia, dynamics and reciprocity.
5. State verbal definitions and define formula for force, work, power, energy and weight.
6. Perform basic mathematical calculations
7. Define momentum.

Week 2

Condition: Lecture, discussion and assigned reading on atomic structure and concepts of electricity.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Relate the history of the atom
2. Identify atomic structure
3. Describe atomic instability
4. Describe the nature of electromagnetism
5. Define electrification and provide examples
6. List the electrostatic laws
7. Identify units of electric current, electric potential and electric power
8. Perform mathematical calculations using ohm's law

Week 3

Condition: Lecture, discussion and assigned reading on electrical concepts, electrical devices and magnetism.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Define electrodynamics
2. Define and state units for EMF, current and resistance.
3. Identify the elements and symbols used in simple electrical circuits.
4. Identify and state the function of electrical measuring devices and protective circuit components.
5. Identify the interactions between matter and magnetic fields
6. Discuss the four laws of magnetism
7. Define the relationships between electricity and magnetism

Week 4

Condition: Lecture, discussion and assigned reading on basic principles of electromagnetism, magnetic induction, coils and electromagnets, motors, generators and transformers.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Explain the basic principles and controlling factors for induction of electricity by magnetic fields.
2. Describe and state applications for simple induction coils and electromagnets.
3. Describe the basic structure and function of the AC generator.
4. Explain the motor principle.
5. Describe the basic structure of AC, DC, and induction motors.
6. Describe the principle of transformer function.
7. Describe the features and turns ratios of step-up and step- down transformers.
8. Calculate changes in voltage and current produced by step-up and step-down transformers.
9. Describe the efficiency of various transformer designs.
10. Describe the structure and function of the autotransformer.

Week 5

Condition: Lecture, discussion and assigned reading on the structure and function of the x-ray tube and tube failure.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Describe the general tube design
2. List and identify the purpose of the external components
3. List and identify the purpose of the internal components
4. Explain the concepts of actual and effective focal spots.
5. Describe the structure of the cathode assembly in a dual- focus tube.
6. Indicate the range of current and voltage values typical of the filament circuit.
7. Describe the parts of the anode and the induction motor
8. Identify the three causes of x-ray tube failure
9. Explain and interpret x-ray tube rating charts

Week 6

Condition: Lecture, discussion and assigned reading on the operating console, rectifiers, rectification systems and timers.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Identify the components of the operating console
2. Explain the operation of the high-voltage generator, including the filament transformer
3. List the types of manual timers and describe the structure of each.
4. Describe the three types of radiation detector used in automatic exposure control devices.
5. Discuss the role of the capacitor in all types of timers.
6. Define rectification.
7. Describe the structure and electrical output of self- rectified, half-wave and full-wave systems.
8. Discuss the structure of a solid-state rectifier and state its advantages over the valve tube and the consequences of rectifier failure in full-wave systems.

Week 7

Condition: Lecture, discussion and assigned reading on the components of the x-ray circuit.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Identify the components of the low-voltage portion of the circuit on a circuit diagram.
2. State the function of each of the components.
3. Describe the x-ray control panel to the components.
4. Identify the components of the high-voltage portion of the circuit on a circuit diagram.
5. Describe the function of each of the components.
6. Identify the components of the filament circuit on a circuit diagram.
7. State the function of each of the components.
8. Describe the general structure of converter power generators.
9. Describe the general structure of battery and capacitor-discharge equipment.

Week 8 **Midterm Exam**

Week 9

Condition: Lecture, discussion and assigned reading on mechanisms of x- ray production and on x-ray beam characteristics and influencing factors.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Identify the conditions needed to produce x-rays.
2. Define the terms space charge and saturation.
3. Describe the bremsstrahlung process of x-ray production.

4. Describe the production of characteristic x-rays in the tube target.
5. Discriminate between beam energy and intensity.
6. List the factors affecting beam intensity and energy.
7. Describe the influences of each factor.
8. Identify the above influences on a graph of the beam spectrum.
9. Calculate how mAs, kVp, added filtration, target material and voltage ripple affect the x-ray emission spectrum.

Week 10

Condition: Lecture, discussion and assigned reading quality management concepts and elements.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Define quality assurance and quality control.
2. List the three major reasons for establishing and maintaining a quality assurance program; explain each one briefly.
3. Describe the areas of responsibility of the various members of the quality assurance team.
4. Describe the role of the federal government in making recommendations for quality assurance procedures and standards.
5. Describe the role of state and local governments in establishing and enforcing standards for equipment performance.
6. Describe the role of voluntary accreditation agencies in quality assurance for x-ray departments.
7. List the criteria for establishing quality control standards.
8. List the general requirements for quality control procedures.
9. Explain the importance of control charts and other quality control records.
10. Briefly describe the process of retake/reject analysis; explain what is meant by reject rate.

Week 11

Condition: Lecture, discussion and assigned reading on QA/QC, visual and manual inspection.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Describe the procedure for evaluating darkroom integrity.
2. Explain how to perform a safelight fog test.
3. List equipment needed for processor monitoring.
4. Explain how to determine developer temperature.
5. Explain the procedure for establishing baseline sensitometric data.
6. Describe the steps used in daily processor monitoring.
7. State the commonly used control limits.
8. Describe the process for determining the replenishment rates of the solutions.
9. Give examples of typical replenishment rates for developer and fixer.
10. List equipment needed for visual/manual checks.
11. Describe inspection of overhead tube, control panel and x-ray table.
12. Describe inspection of fluoroscopic tower and video systems.
13. Discuss inspection of protective apparel, viewboxes, and film storage.

Week 12

Condition: Lecture, discussion and assigned reading on methods of evaluating the radiation beam output, timer accuracy, generator linearity, and reproducibility of exposure.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Define the terms accuracy, reproducibility and linearity as used in quality control procedures.
2. Describe the procedure for testing the accuracy of a radiographic timer; state acceptable variation.
3. Describe the procedures which may be used to evaluate reproducibility of exposure with manual and phototimed exposures; state the limits of acceptable variation.
4. Calculate mR/mAS for given data.

5. Describe the procedures used to evaluate the linearity of an x-ray control; state the limits of acceptable variation.

Week 13

Condition: Lecture, discussion and assigned reading on measurement of beam quality and adequacy of filtration.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Define HVL and explain its relationship to beam energy.
2. Describe the procedure for determining HVL; state the recommended minimum value at 80 KVP.
3 Describe the simple procedure for determining adequacy of filtration.
4. Briefly explain the structure and use of the KVP test cassette.

Week 14

Condition: Lecture, discussion and assigned reading on evaluation of beam geometry, tests of collimator accuracy, beam perpendicularity, and on quality control tests of screens and grids.

Learning Outcomes: At the end of the lecture, the student will be able to:

1. Describe two procedures for demonstrating the congruence of the collimator light field with the x-ray field.
2. State the federal recommendation for the maximum permitted misalignment.
3. Describe a test for the perpendicularity of the central ray; state permitted variation.
4. Describe the procedures for evaluating the accuracy of beam restriction in both manual and automatic modes.
5. Describe the method of testing the accuracy of bucky alignment and uniformity of density.
6. Explain how to differentiate between causes of non-uniform exposure.
7. Describe the procedure for inspecting and cleaning intensifying screens.
8. Describe the test for film-screen contact and the criteria for evaluation.
9. Describe a method of testing for uniformity of screen speed among cassettes in a department.

Week 15 **Final Exam**